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A WARBLE TONE GENERATOR

R. R. DUTTA GUPTA

DEPARTMENT OF COMMUNICATION ENGINEERING, INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR, INDIA

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ABSTRACT. A warble tone generator using a simple phase shift oscillator has been described. Actually two similar oscillators are used, one having a very low fixed frequency corresponding to the frequency of wobbulation This low frequency oscillator voltage is applied to the grid of a triode which is used as a variable resistance element in the main oscillator of varying frequency. The relative importance of the different R C sections of a phase-shift oscillator from the point of view of frequency stability has also been discussed. It has been shown, for example, that the variation of the first resistance of the three sections gives maximum percentage variation of frequency

1. INTRODUCTION

The need of a warble tone generator in acoustic measurements is well known. Thus in measurement of reverberation time of an auditorium if a pure tone is sounded it is likely that a number of normal modes will be excited. As a result, when the sound source is turned off, the sound pressure at any point in the auditorium decays in an irregular manner. Such irregularities can be reduced by using a warble tone

Hunt (1936) and Burger (1943) have described methods of producing warble tones. The former uses a rotating condenser which is connected in parallel with the main capacitance of an $L-C$ circuit and this in turn varies the frequency of the oscillator circuit. The latter, however, uses a multivibrator for generating a sawtooth wave which is then amplified by a valve whose average plate current also serves to magnetize the core of a variable reactor which is connected to its plate. This variable reactor, in parallel with condensers connected across it, forms a frequency modulated oscillator circuit. In Hunt's method one has to use a mechanically rotating part which, from the point of view of operation, is not quite convenient. Burger's method of producing warble tone is, on the other hand, very round about. In the following is described a new type of warble tone generator which is very simple in design and at the same time avoids all mechanically rotating parts.

2. PRINCIPLE OF THE NEW GENERATOR

The circuit of the new warble tone generator is shown in figure 1. It represents a conventional phase shift oscillator [Ginzton and Hollingsworth 1941,] with three sections of resistance capacitance networks at the output of the 6AC7 oscillator tube. The plate load R_L is chosen to be low so that the 6AC7 plate voltage is exactly 180° out of phase with regard to its grid voltage. The additional

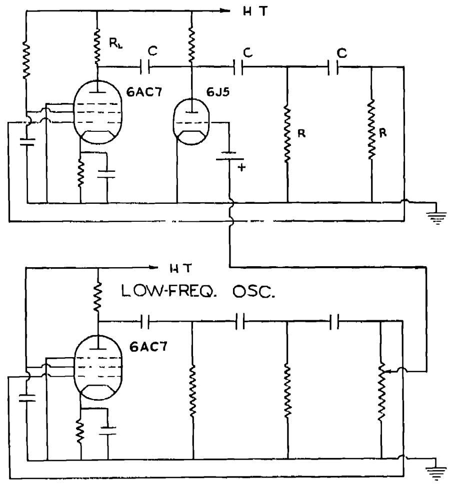

Fig. 1. Circuit diagram of the warble tone generator.

180° phase shift for oscillations to occur is provided by the *R-C* sections as usual. The 6J5 triode acts as a variable resistance tube which is effectively connected in shunt with the resistance on its plate. The variation of this resistance gives 180° phase shift in the network at different frequencies and thus the oscillator frequency changes. The degree and speed of frequency modulation depends respectively upon the voltage and frequency applied at the grid of the modulation tube 6J5. This voltage is supplied from a similar low frequency phase shift oscillator.

In the circuit of figure 1 the first resistance of the three R-C sections was varied because this gives maximum frequency modulation. Considering the simplified circuit as given in figure 2., we can write

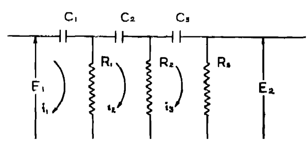

Fig. 2. Phase shifting network

$$\begin{bmatrix} E_1 \\ 0 \\ 0 \end{bmatrix} = [Z] \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix}$$

where $[Z]$ = matrix of the transformation.

$$= \begin{bmatrix} \left(R_1+\frac{1}{j\omega C_1}\right) & -R_1 & 0 \\ -R_1 & \left(R_1+R_2+\frac{1}{j\omega C_2}\right) & -R_2 \\ 0 & -R_2 & \left(R_2+R_3+\frac{1}{j\omega C_3}\right) \end{bmatrix}$$

or,

$$\begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = [Z]^{-1} \begin{bmatrix} E_1 \\ 0 \\ 0 \end{bmatrix}$$

where, $[Z]^{-1}$ = inverse matrix of $|Z|$

If $|Z|$ = network determinant,

$$i_3 = \frac{E_1 R_1 R_2}{|Z|}$$

or, transfer function $$T = \frac{E_2}{E_1} = \frac{R_3 i_3}{E_1} = \frac{R_1 R_2 R_3}{|Z|} \quad \dots \quad (1)$$

For oscillation to take place, phase shift in the network must equal π. This condition is satisfied if the imaginary part of $|Z|$ vanishes.

Or, $$\frac{1}{\omega C_3}\left(R_1^2 - \frac{1}{\omega^2 C_1 C_2}\right) + \frac{R_1(R_2+R_3)}{\omega}\left(\frac{1}{C_1}+\frac{1}{C_2}\right) + \frac{R_2 R_3}{\omega C_1} + \frac{R_1 R_2}{\omega C_3} = 0$$

This gives,

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{\left(\frac{R_1R_2+R_2R_3+R_3R_1}{C_1}+\frac{R_1R_2+R_1R_3}{C_2}+\frac{R_1R_2}{C_3}\right)C_1C_2C_3}} \quad \dots \quad (2)$$

Now, if $C_1 = C_2 = C_3 = C$,

$$f = \frac{1}{2\pi C\sqrt{3R_1R_2+2R_1R_3+R_2R_3}} \quad \dots \quad (3)$$

From this expression we see that when the three resistances are of the same nominal value and one of them is varied, the change in frequency of oscillation is maximum due to variation of R_1. If, therefore, good frequency stability is required, greatest attention should be given to R_1. On the other hand, if large variation in frequency is wanted by varying one of the three resistances it is R_1 which should be made to vary by the modulating signal.

If, furthermore $R_2 = R_3 = R$, the expression for f becomes,

$$f = \frac{1}{2\pi RC\sqrt{1 + \frac{5R_1}{R}}} \qquad \ldots \quad (4)$$

This is the frequency which holds in our set up.

3 RESULTS

The results of static modulation characteristics of the main oscillator are given in Table I and are plotted in figure 3.

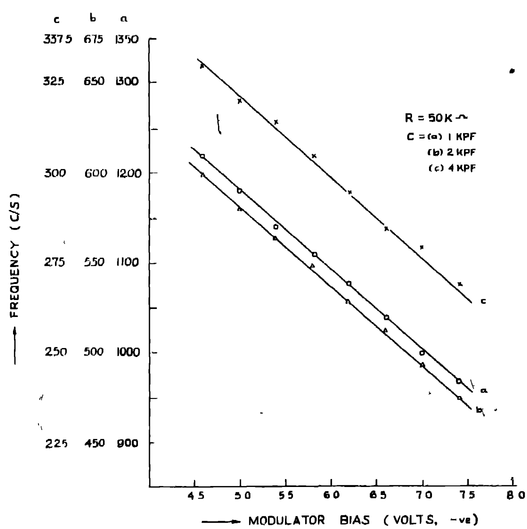

Fig. 3. Static characteristics of the warble tone generator.

TABLE I

Modulator bias (Volts, $-VE$)	Frequency of oscillator (c/s)		
	$R = 50K\ \Omega$ $C = 1\ KPF$	$R = 50K\ \Omega$ $C = 2\ KPF$	$R = 50K\ \Omega$ $C = 4\ KPF$
4.6	1220	600	330
5.0	1180	580	320
5 4	1140	565	315
5.8	1110	550	305
6.2	1080	530	295
6 6	1040	515	285
7.0	1000	495	280
7 4	970	475	270

It is to be noted that the shunt resistances of the R-C sections have been kept fixed and the series capacitances only have been changed for obtaining different centre frequencies, because otherwise both the degree and linearity of modulation would be affected as seen from eqn (4).

It is seen from the above table that linear frequency variation is obtained up to about $\pm$ 12% of the centre frequency. With further increase in deviation, however, the amplitude changes—the smaller the bias the smaller is the resistance 6J5, and lower is the amplitude of oscillation. The amplitude modulation has been found to be quite small over a range of about $\pm$12% of the centre frequency

For effective measurement of reverberation time of an auditorium the warble tone is generally frequency-modulated to about 10% of the centre frequency. Further, as pointed out by Hunt (1933), the ratio of twice the maximum frequency deviation from the mean frequency to the modulating frequency should exceed 3. This meant that the modulating frequency should be less than one-fifteenth of the oscillator mean frequency If the lowest mean frequency be 100 c/s, fm should not exceed 7 and, therefore, if the l f oscillator is designed for a frequency of 7 c/s. all the requirements are fulfilled.

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